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How to cite:

Ko, J.; Im, M.; Lee, H. M.; Lee, M. G.; Hopwood, R. H.; Serjeant, S.; Smail, I.; Hwang, H. S.; Hwang, N.; Shim, H.; Kim, S. J.; Lee, J. C.; Lim, S.; Seo, H.; Goto, T.; Hanami, H.; Matsuhara, H.; Takagi, T. and Wada, T. (2009). AKARI observation of early-type galaxies in Abell 2218. In: Onaka, Takashi; White, Glenn; Nakagawa, Takao and Yamamura, Issei eds. AKARI, A Light to Illuminate the Misty Universe. Astronomical Society of the Pacific Conference Series, 418. San Francisco, USA: Astronomical Society of the Pacific, pp. 495–498.

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AKARI Observation of Early-Type Galaxies in Abell 2218

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Abstract. We describe the *AKARI* InfraRed Camera (IRC) imaging observation of early-type galaxies (ETGs) in A2218 at $z \simeq 0.175$. With the imaging capability at 11 and 15 μm , we investigate mid-infrared (MIR) properties of ETGs in the cluster environment. Among our flux-limited sample of 22 optical red sequence ETGs, we find that more than 50% have MIR-excess emission, and the most likely cause of the MIR excess is the circumstellar dust emission from asymptotic giant branch (AGB) stars. The MIR-excess galaxies reveal a wide spread in $N3 - S11$ (3 and 11 μm) colors, indicative of a significant spread (2–11 Gyr) in the mean ages of stellar populations. They are also preferentially located in the outer region, suggesting the environment dependence of MIR-excess ETGs over an area out to a half virial radius.

1. Introduction

Numerous studies of early-type galaxies (ETGs hereafter) in cluster environments have revealed that their stellar populations are predominantly old and passively evolved from high redshifts where most of their stars formed, as shown in the tight color-magnitude relation (CMR; e.g., Bower et al. 1992; Kodama & Arimoto 1997).

When observed in the infrared (IR), some ETGs exhibit excess emission over photospheric emission (Knapp et al. 1992; Xilouris et al. 2004). The IR excess can be originated from various reasons, such as circumstellar dust around AGB stars (Knapp et al. 1992), star formation, and AGN activities (Quillen et

al. 1999). Recent *Spitzer* studies indicate that the mid-IR (MIR) excess is due to dusty AGB stars for most ETGs in the red sequence (Bressan et al. 2006). According to the model which incorporates the dust emission from AGB stars, the MIR excess is prominent if the luminosity weighted mean age of the stellar populations is young (Piovan et al. 2003, hereafter P03).

The previous *Infrared Space Observatory* (*ISO*) study showed the lack of MIR-excess ETGs at the central region of A2218 (Biviano et al. 2004), while the analysis of optical/NIR imaging and spectroscopy of this cluster have shown a wide dispersion in the stellar ages of faint ETGs (Smail et al. 2001; Ziegler et al. 2001). The two results seem contradictory, and a wide-field and more complete MIR imaging could offer a solution. Using the *AKARI* space telescope (Murakami et al. 2007) that offers a wide-field imaging at 11 and 15 μm for the first time, we examine the relation between the cluster environment and the MIR excess of ETGs in A2218, a galaxy cluster at $z = 0.175$ (e.g., Biviano et al. 2004).

2. The Data

The *AKARI* observation for the A2218 field was carried out using six broadband filters (3–24 μm) of the InfraRed Camera (IRC; Onaka et al. 2007). We covered a 15×15 arcmin² field centered on the X-ray brightness peak of A2218, using 4 IRC tiles (Figure 1), and collected 39 *AKARI* cluster member ETGs with optical data from Ziegler et al. (2001, hereafter Z01). The 5σ detection limit of the S11 image, which is used to examine the MIR properties of ETGs, reaches to 19.6 mag.

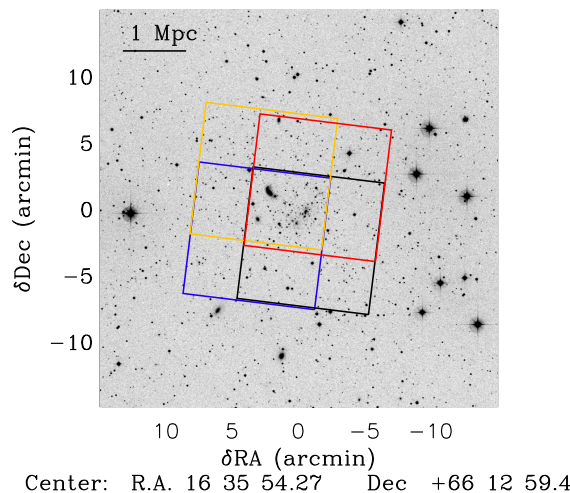


Figure 1. Four rectangles indicate the *AKARI* coverage of A2218 on DSS red image. The coordinates show relative position to the center of the cluster in arcmin. North is up and east is to the left.

3. Results and Discussion

Figure 2 shows the observed optical-MIR spectral energy distributions (SEDs) of three sample ETGs, with best-fit model SEDs overplotted. Based on the strength of MIR excess, we categorize the sample into three sub-groups; strong-, mid-, and weak/no MIR-excess galaxies. We performed a least squares fit of SEDs using three different models— spectral synthesis models with or without AGB dust from P03 (*AGB* or *noAGB* model), and templates of star-forming galaxies from Chary & Elbaz (2001; *SF* model). We first note that the P03 *noAGB* model fails to fit the strong/mid MIR-excess ETGs. Next, we find that most MIR-excess ETGs returned acceptable SED fits to the P03 *AGB* model with any metallicities (solar, 40% solar, and 20% solar) if we consider the IR portion of the SEDs alone. This result suggests that MIR excess is less sensitive to metallicities than ages, with a distinct picture that the younger galaxies have the stronger MIR excess. However, the AGB dust emission is not the only possible reason for the MIR excess. In some cases, it is difficult to exclude star-forming activities as the origin of MIR excess using current data alone. Deeper 70 μm or/and UV data could offer an effective way to solve this problem.

In order to investigate the dependence of MIR-excess ETGs on the cluster environment, we plot the spatial distributions of our *AKARI* cluster ETGs with the contour maps of the *Chandra* X-ray emission in Figure 3. Among our S11-detected sample of 11 optical red sequence ETGs, we find that about 64% (7/11) of the outer galaxies show MIR excess, while only 18% (2/11) of the inner ones do so. These MIR-excess galaxies are also relatively faint ones in our sample. We note that there are ETGs in the inner region as faint as the MIR-excess ETGs in the outer region, but they do not show clear MIR excess. From these results, we conclude that these MIR-excess galaxies are fainter, and preferentially located in the outer region of the cluster, suggesting that they could be the descendants of infalling field galaxies transformed into ETGs.

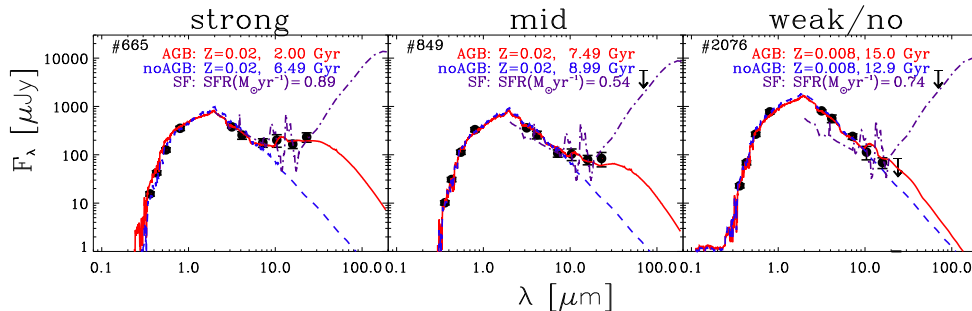


Figure 2. The observed SEDs of the S11-detected galaxies with Z01 optical and the *Spitzer* 24/70 μm data available. The best-fit lines of three different models (*AGB*: solid, *noAGB*: dashed, *SF*: dashed-dotted) are overplotted with 1σ error bars. Arrows represent the 3σ detection limit (From Ko *et al.* 2009).

Acknowledgments. We thank L. Piovan for providing his SED model. This work is based on observations with *AKARI*, a JAXA project with the par-

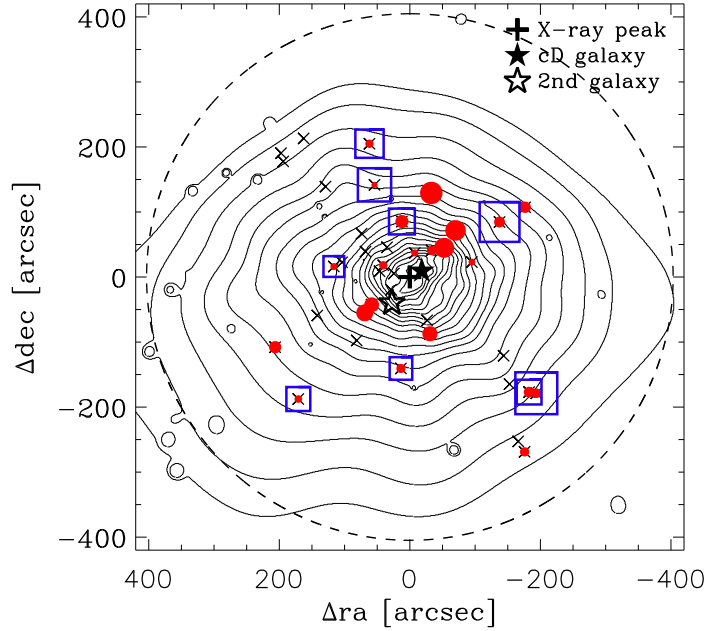


Figure 3. The spatial distributions of the 39 cluster ETGs with the X-ray contours adopted from Maughan et al. (2008). The filled circles are ETGs with $N3 < 18$ mag, and the size is proportional to $N3$ flux. The squares are MIR-excess ETGs, and the size is proportional to F_{11}/F_3 flux density ratios. The dashed circle corresponds to the radius R_{500} (From Ko et al. 2009).

ticipation of ESA. We acknowledge the Creative Research Initiatives program, CEOU of MEST/KOSEF. RHH, SBGS, and IRS also acknowledge support from STFC.

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